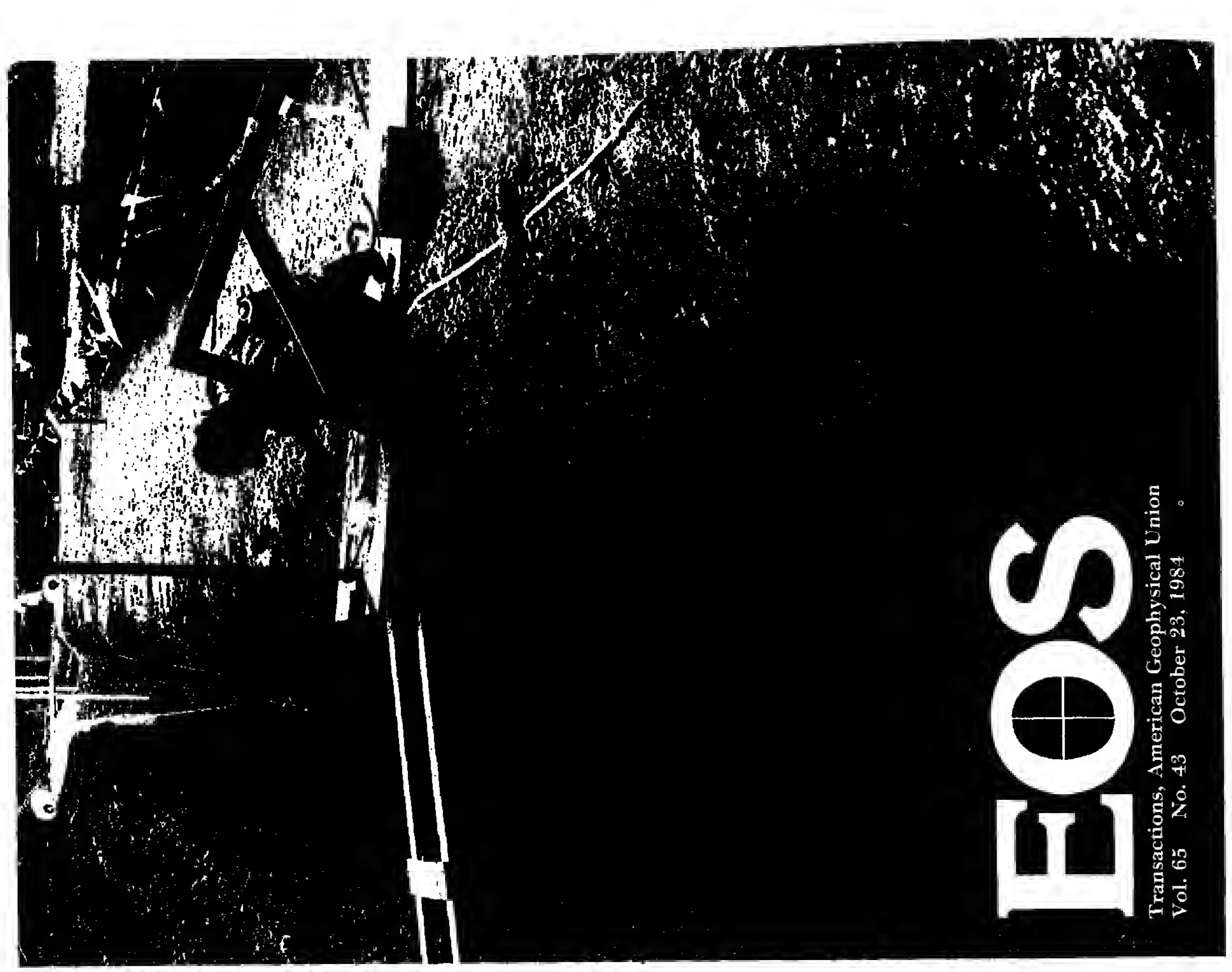

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Uranium in the Earth's Core

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That there is no radioactivity in the earth's core is a concept that has long been held. The reason is that the major radioactive elements, potassium and uranium, exist as siderophobic compounds, such as silicates and oxides, in the earth's mantle and thus were thought to be immiscible with the metal core. An experimental measurement of the binary system of steel and UO_2, however, shows that above 3120 K the system is a two-phase liquid, the one rich in UO_2 and the other poor in UO_2. The phase diagram predicts that there must be a temperature above which there is total miscibility between UO_2 and steel. This temperature may be above the boiling point of UO_2, estimated as 3750 K. The temperature at the core-mantle interface of the earth's interior is estimated most recently as 3130 K. Thus there is a strong likelihood that uranium exists in the earth's metal core. Hence the natural alpha radioactivity of uranium offers a power source for the earth's magnetic dynamo.

Introduction

A heat source of 5×10^{16} erg/s in the earth's core is estimated to be more than sufficient to sustain convection and thus to maintain the earth's magnetic field [*Jacobs*, 1975, p. 267]. The possible heat sources, radioactive potassium and radioactive actinides, are expected to exist, however, mainly as siderophobic compounds, such as oxides and silicates, which are immiscible in the earth's metal core [*Urey*, 1952, p. 92].

Considerable discussion has appeared in the literature about the possibility of potassium having been incorporated into the metal core, for example, in the primitive differentiating earth. Less attention has been given to the possibility of uranium existing in the core [see *Jacobs*, 1975, pp. 204–208; *Somerville and Ahrens*, 1980; *Ahrens*, 1982]. In fact, uranium appears to be steadily incorporated into the metal core at all times, not only in the primitive differentiating earth but at the present time as well. The evidence is experimental.

Except for hypothetical incorporation of potassium into the core in the primitive differentiating earth, the other heat source suggested has been the continuous growth of the iron core of the earth from migration of iron in the mantle and the corresponding release of gravitational energy. The experiment of *Hodkin and Potter* [1980] now makes it likely that uranium is steadily dissolving into the core and supplying radioactive heat.

The Experiment

The experiment was performed by *Hodkin and Potter* [1980] as follows. Stainless steel and UO_2 were melted together by an arc discharge between a tungsten cathode and an anode crucible until observation of the melt was obscured by vapor of the uranium oxides at temperatures more than 3120 K. After melting had proceeded for 7 minutes, the crucible was cooled. This cooling produced an ingot which was examined by electron probe microanalysis. In the molten state, two immiscible liquids had been present. One was UO_2 with 1% weight of steel, and the other was steel with 23% weight of UO_2. The experimenters conclude that there is a temperature above which there is total miscibility between UO_2 and steel; however, that temperature may be above the boiling point of UO_2, estimated as 3750 K.

The projected phase diagram for UO_2-steel is shown in Figure 1, where the temperature in degrees Kelvin is plotted versus weight percent. The experimentally measured points lie on the uppermost solid line at 99% and 23% weight of UO_2, respectively, at a temperature somewhat higher than 3120 K.

One may inquire whether the presence of 2% Mn, 10% Ni, and 16% Cr in the steel may substantially affect the two-phase nature of the liquid-liquid region of the phase diagram. The answer appears to be no, judging from other experiments made by *Hodkin and Potter* [1980]. In one of these, they melted stainless steel, UO_2, Mo, Ru, Rh, and Pd. The condensate contained 41% weight UO_2. Even at temperatures that were probably little above the melting point of uranium, there was 20% weight of UO_2 dissolved in liquid stainless steel.

Hodkin and Potter [1980] also present a possible U-C-O phase diagram for 2550 K which shows that uranium can be reduced by carbon (which presumably can be present in the earth's core as it is present in iron and steel) to a region of two liquids, the one being rich in U and the other being rich in UO_{2-x}. If this occurs, then there is a good probability that the U-rich liquid will mix with the liquid iron at all values of weight percent (see phase diagram of Fe versus U by *Hultgren et al.* [1971, p. 895]).

What might be the effect of high pressure on the UO_2-steel phase diagram? The review and analysis of *Anderson* [1982] attempts to answer this question in the form of the effect of pressure on the temperature at the core-mantle interface of the earth. The answer appears to be that the phase boundaries in Figure 1 may be shifted up by pressure but down by chemical effects of small amounts of other substances. Anderson balances these perturbations against each other to arrive at 3131 K as the temperature of the core-mantle boundary.

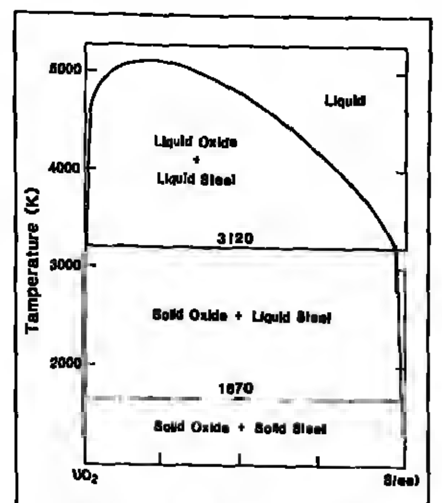

Fig. 1 Phase diagram for UO_2 and steel. The two immiscible liquids in the liquid-liquid region were measured at a temperature somewhat above 3120 K.

Uranium Radioactivity in the Earth's Core

The experimental demonstration of two liquids coexisting in the liquid system of UO_2 and steel at temperatures 3120 K up to perhaps 5000 K and total miscibility above that leads us to consider that there is probably continuous absorption of uranium from the mantle into the earth's metal core. Radioactive decay of uranium in the earth's core offers a power source for the dynamo that creates and maintains the earth's magnetic field.

After 4.6 b.y. of existence of the solar system, the energy in the decay chain of uranium is mostly that from ^{238}U and amounts to 32.9 MeV per atom. The volume of the core is 1.77×10^{23} cm³ at a density of 14.6 gm/cm³ [*Anderson*, 1982] and contains 2.58×10^{21} gm of iron. At the cosmic abundance of uranium it also contains 1.45×10^{18} gm U, which provides an alpha particle heat source of 2.7×10^{17} erg/s in the core. According to *Jacobs* [1975, p. 267], the ohmic dissipation of currents in the core which maintain the geomagnetic field are of the order of 5×10^{16} erg/s. Thus the heat from uranium in the core at its natural abundance appears to be sufficient to power the dynamo, assuming an efficiency of about one tenth.

Additional uranium may enter the core (as a component of the two-liquid system) from the lower mantle. This addition is suggested by an analysis of *Schubert and Spohn* [1981], who find that the lower mantle is depleted in radioactivity and can contain only 8% or less of all the heat-producing radioactive elements in the mantle. Other estimates of the fraction of the mantle that has been depleted range from ¼ to ½ (see references of *Schubert and Spohn*, [1981]).

Conclusion

Experiments on the phase diagram of UO_2-stainless steel, made for breeder research, show that at temperatures equal to that of the core-mantle interface of the earth a binary liquid system exists, containing two liquids, the one rich in UO_2 and the other poor in UO_2. The experiments also show that alteration of the system with elements intermediate in the periodic table have little effect on the phase diagram. The effect of pressure has been studied by others and thought to be small. Therefore we infer that uranium may well exist in the earth's core in significant quantities and at a natural abundance that is sufficient to maintain the earth's magnetic field. It may also be continuously extracted from the lower mantle, adding to the uranium component of the core.

The phase diagram of UO_2-iron should be studied more thoroughly. Thorium oxide–uranium may behave similarly. The decay time of thorium is about three times longer, but its abundance is six times greater. Its phase diagram should be studied also.

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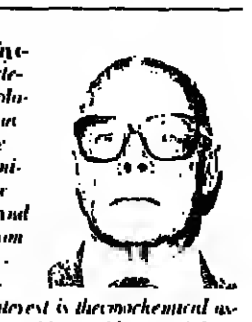

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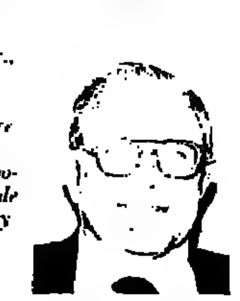

Terry C. Wallace, Sr., *is the Associate Division Leader for Energy Technologies, Materials Science and Technology Division, Los Alamos National Laboratory. His interests include high-temperature chemistry research, development of new materials for utilization in adverse environments, and development of materials science and technology capabilities needed for lunar bases and space activities in the 21st century.*

Leona Marshall Libby *is consultant at Los Alamos Scientific Laboratory and adjunct professor of engineering at University of California at Los Angeles.*

News

1984 Solar Eclipse

At a recent meeting of the incoherent scatter radar user community an experiment was planned to observe the ionospheric and thermospheric response to the May 30, 1984, annular solar eclipse with the meridional radar chain whose elements span the eclipse path. Investigators from the National Center for Atmospheric Research (NCAR), the Air Force Geophysics Laboratory, SRI International, Arecibo Observatory, and the Massachusetts Institute of Technology (MIT) Haystack Observatory were involved in this experiment. The operation of the incoherent scatter radars is sponsored by the National Science Foundation Atmospheric Sciences Division.

Three radars participated in the observations of the eclipse effects: Arecibo (18°N), Millstone Hill (43°N), and Sondrestrom (67°N). The Millstone Hill radar was within 3° latitude of the path of the eclipse and experienced a maximum solar obscuration of 92% at 1705 UT. The eclipse duration was approximately 3 hours. Measurements at Millstone Hill included electron density, plasma temperatures, and ion drifts overhead using the 67-m zenith antenna and to the south and southwest at low elevations (10–15°) using the 46-m steerable antenna to map drift velocity vectors and extend the observations towards the Arecibo station. Millstone Hill began gathering observations at 1200 UT and continued through the eclipse to 2200 UT. The automated data processing and graphics capabilities at Millstone Hill were utilized to obtain initial results of the eclipse observations within 12 hours of the completion of the experiment, and the data were placed in the remotely accessible user data base on the Millstone computer. These data are available to the research community on request.

The color photograph on the cover of this issue illustrates the results obtained from Millstone Hill with the steerable antenna directed to the southwest. This beam intersected the eclipse center line 5° west of the Millstone Hill meridian at 300 km altitude, where maximum obscuration occurred at 1641 UT. The frames show (top to bottom) color-coded intensity contours of the electron density, ion temperature, electron temperature, and ion drift line-of-sight velocity as a function of altitude up to 600 km and universal time from 14 to 20 hours. The electron temperature decreased by 750 K at 300 km centered on the eclipse time, while the electron density minimum was 70% of the preeclipse value at that altitude and occurred 30 minutes later. There was a much smaller effect on the ion temperature. The plasma drift velocity developed a northward component of ~75 m/s as the eclipse effects began. This latter effect may be a result of some geomagnetic activity (Kp = 3).

The ionospheric data collected at Millstone Hill as well as that from the other radars will be analyzed in detail, and thermospheric parameters such as the exospheric temperature and the meridional neutral wind component will be derived from the measurements. These, in turn, will be compared to predictions already made at NCAR for the eclipse using the Thermospheric General Circulation Model. In a preliminary review it was seen that the model predictions are generally consistent with the observed drop in electron density and electron temperatures. Detailed quantitative comparisons require further study.

This news item was submitted by Joseph E. Salah, *Director, MIT Haystack Observatory.*

Land and Seabed Deformation

The development of techniques to monitor undersea and ground surface deformation and sea level changes will be highlighted at a session of invited geodesy papers at the AGU Fall Meeting, to be held in San Francisco, Calif., December 3–7, 1984.

The oceans conceal the earth's largest sudden deformation events. Subduction earthquakes at great plate boundaries produce 10–20-m motions of the crust near offshore trenches. Inflation of undersea volcanoes and the spreading of midocean rifts also produce large changes that may go unnoticed. The great tsunami-generating earthquakes may be associated with unusually large vertical movements of the seabed; these earthquakes also may cause vast undersea landslides. Technologies to predict these large movements have potential for improving earthquake prediction, tsunami warning, and prediction of volcanic eruptions. Fred Speiss, chief editor of a recent National Academy of Sciences book on undersea deformation, will chair this session.

Presentations at another geodesy session will detail efforts to monitor and record the ground surface deformation that precedes earthquakes. Measurement of deformation remains a vital and elusive goal of earth scientists. By understanding these processes, geologists hope to learn more about predicting when and where large quakes will occur. The best results achieved to date in several different projects will be presented at the session, along with the strategy and expectations for

News (cont. on p. 786)

News (cont. from p. 785)

the monitoring network at Parkfield, Calif.

Scientists from the U.S. Geological Survey (USGS), working in cooperation with the State of California and several U.S. universities and institutes, have chosen a stretch of the San Andreas Fault at Parkfield, Calif., midway between San Francisco and Los Angeles, to concentrate efforts at monitoring ground surface deformation. The site was chosen for its relative "predictability": This stretch has ruptured five times since 1857, about once every two decades. The geologists believe that the next rupture will take place at Parkfield before 1990.

The last two Parkfield quakes, in 1934 and 1966, were each preceded by a magnitude 5 foreshock located 1.6 km from the main shock; each occurred 17 minutes before the main shock. According to geologists involved, this makes Parkfield a "uniquely well-behaved" site for deploying networks of high precision to monitor ground deformation and precursory seismicity.

Such a network is largely in place. The instruments that make up this network include some 30 high-gain seismometers. Data from these instruments are telemetered back to the USGS at Menlo Park, Calif., and in some cases are computer-analyzed in real time. About 50 strong motion instruments also have been deployed to give seismologists a reading on the actual quake.

The geodetic network at Parkfield makes use of the large-scale geodimeter network used throughout California as well as a two-color laser geodimeter to measure movement along either side of the fault. The laser geodimeter records information from a dozen baselines from 4 to 8 km in length. Other instruments deployed include downhole strain measurement devices and low-sensitivity creep meters. —*DWR*

Tropospheric Chemistry Research

To answer basic science questions about man's influence on the earth's troposphere and how to protect it, a National Research Council (NRC) panel has proposed a long-term international research program to study global tropospheric chemistry. The panel estimates that initial funding of $10–$20 million per year will be required, increasing yearly for the program's minimum 10-year life.

According to the panel, this proposed effort would be different from existing atmospheric chemistry programs, such as those concerning acid precipitation, for two reasons: First, the proposal calls for a long-term effort, not a short-term reaction to political pressures or, as noted by one member of the panel, "crisis response." Second, the panel emphasized the global framework and international cooperation requested in the proposal. According to panel members, many existing studies are urban or regional in nature and do not have the scope required to gain an overall understanding of the complex troposphere. Existing programs are seen as a foundation for what is envisioned as an all-encompassing program.

Robert A. Duce, chairman of NRC's Global Tropospheric Chemistry Panel and professor at the University of Rhode Island, speaking at a briefing on October 17, in Washington, D.C., summarized the overall objectives of the project: To find out how and to what degree the biosphere controls earth's climate and to determine over what time periods this takes place.

Long-term objectives of the program are:

"1. To understand the basic chemical cycles in the troposphere through field investigations, theory aided by numerical modeling, and laboratory studies.

"2. To predict tropospheric responses to perturbations, both natural and human-induced, of these cycles.

"3. To provide information required for the maintenance and effective future management of the atmospheric component of the global life support system."

Specific science objectives of the proposed study include evaluation of biological sources of chemicals in the troposphere, determination of the global distribution of trace gases and aerosol particles, investigation of photochemically driven transformation processes as well as wet and dry removal processes for trace gases and aerosol particles, and the development of global tropospheric chemistry systems models.

In its report, called "Global Atmospheric Chemistry, A Plan for Action," the panel suggested that funding of individual investigations and investigators could be handled through already established National Science Foundation (NSF) and National Aeronautics and Space Administration (NASA) channels but indicated only that overall science management of such a program should be assigned to "an appropriate U.S. scientific organization." Other organizations expected to be involved include the National Oceanic and Atmospheric Administration (NOAA), the Department of Energy (DOE), the Environmental Protection Agency (EPA), and the Department of Defense (DOD), as well as universities, private research groups, and industry.

Members of the panel indicated that a future workshop, to be attended by 50–80 members of the U.S. and international atmospheric chemistry community, will be held to begin pinpointing specific research needs within the framework of the proposal. A steering committee is now in the process of organizing this meeting.—*DWR*

Atlantic Hot Vent Discoveries

By using the chemical concentration of water as a key to location, scientists from the National Oceanographic and Atmospheric Administration (NOAA) and several U.S. universities have identified three new Atlantic Ocean sites of mineral-rich hot vents. This discovery brings the total number of known Atlantic Ocean vent sites to four.

These Atlantic Ocean discoveries lead scientists to speculate that venting sites may be as prevalent in the Atlantic as they are in the Pacific. According to Peter Rona of NOAA's Atlantic Oceanographic and Meteorological Laboratory in Miami, Fla., hot seabed vents were thought to occur primarily at fast spreading undersea ridges, such as those that exist in the Pacific Ocean, but not at the relatively slow spreading ridges, such as those found in the Atlantic.

In 1982 a venting area was discovered in the Atlantic along the mid-Atlantic ridge about 2,800 km east of Miami. Large deposits of manganese were associated with the site. The latest discoveries are located along the ridge, 800–1,600 km south of the original site.

In related news, scientists at the Scripps Institute of Oceanography have reported the discovery of biological communities in the Gulf of Mexico similar to those found in the Pacific hot vent areas.

According to Charles Paull, a member of the Scripps Geologic Research Division who took part in the research cruise last February when the discovery was made, the Gulf of Mexico communities are similar in their biology but exist within an entirely different geological setting. Chief among the differences is a lack of the high temperatures that have been associated with the Pacific vent sites. Instead, scientists involved believe that the minerals needed to sustain the communities may be supplied from the Florida escarpment. Paull will present his findings at the AGU Fall Meeting, to be held in San Francisco, Calif., December 3–7, 1984.

Geophysicists

Carroll Ann Hodges has been appointed assistant chief geologist for the U.S. Geological Survey's Western Region, headquartered in Menlo Park, Calif. She succeeds ***G. Brent Dalrymple***, who has returned to research studies in isotope geology at Western Region headquarters after serving as assistant chief geologist for 3 years. Hodges joined the USGS Branch of Astrogeological Studies in Menlo Park in 1970. Her research has consisted mainly of topical studies and mapping projects on the moon and Mars. She was principal investigator in Apollo 16 geologic analyses both before and after that lunar mission. Since 1982 she has served with the survey's Branch of Western Mineral Resources as chief of an international minerals resource assessment project. In 1980–1981, Hodges was the AGU Congressional Science Fellow on Capitol Hill. She is a member of the AGU Public Affairs Committee.

Rafael N. Sanchez has been appointed visiting professor with the University of Buenos Aires and was accepted as a member-correspondent of the Academia Nacional de Ingenieria, Argentina. Sanchez, a professor of Laval University, is currently on sabbatical.

In Memoriam:

Charles J. Doly, 34, died September 20, 1984. A member of the Hydrology Section, he joined AGU in 1979.

Paul A. Dutch, 68, a member of the Atmospheric Sciences Section, died recently. He joined AGU in 1963.

Hiroyuki Fukuyama, 36, died in August 1984. A member of the Volcanology, Geochemistry, and Petrology Section, he joined AGU in 1984.

AGU Lost Members

Mail to the following members has been returned, and we are unable to locate forwarding addresses. If you have information on any of them, please contact AGU by mail or call toll free at 800-424-2488.

- Eric D. Leavitt, Calgary, Alberta, Canada.
- David L. Fowler, Rohnert Park, California.
- David E. Harnish, Madison, Wisconsin.
- Lutz U. Schaefer, Mainz, West Germany.
- Michael W. Tubman, Singapore.
- David B. Wenner, Rondebosch, South Africa.
- James E. York, Anchorage, Alaska.

Books

Precambrian Sulphide Deposits

R. W. Hutchinson, C. D. Spence, and J. M. Franklin (Eds.), *H. S. Robinson Memorial Volume, Geol. Assoc. of Can. Spec. Pap. 25*, Geological Association of Canada, Toronto, Ontario, vii + 792 pp., 1982, $57.00.

Reviewed by Bruce R. Doe

This book is dedicated to Howard S. Robinson, who was born and educated in the United States, but who spent his professional career in Canada with McIntyre Porcupine Mines, concentrating on Precambrian mineral deposits. Although his career in mineral exploration was distinguished, his major contribution to earth science was probably as one of the founders of the Geological Association of Canada, an institution to which he made a bequest in his will. With this background, the strong emphasis on Canadian Precambrian mineral deposits should come as no surprise; of the 23 papers in this book, 21 are solely or primarily devoted to Canadian deposits. The two exceptions—those describing the Balmat, N. Y., zinc mines (at times the largest zinc producer in the United States) and the Crandon, Wisconsin, volcanogenic zinc-copper massive-sulfide deposit (the largest deposit of its kind found in the 1970's)—are each within a couple of hundred kilometers of the Canadian border. Although the title of the book is more expansive than the actual topics discussed, Canada is rich in Precambrian rocks and ore bodies, and Canadian scientists have been especially alert to tectonic influences in the formation of mineral deposits. These features, plus the fact that the country contains a very well exposed expanse of Archean rocks which is the largest in the world, facilitate the study of early crustal evolution and make the book of particular interest to geophysicists.

The book comprises two parts. Part I, which may be of greatest interest to geophysicists, is composed of four regional papers: one on the Superior, Slave and Churchill provinces by J. M. Franklin and R. I. Thorpe, a second on the Grenville province by A. L. Sangster and J. Bourne, a third on the Purcell Supergroup by T. Hoy (the Canadian equivalent of the Belt Supergroup in Canada), and the fourth on the Mackenzie fold belt by J. D. Aitken. Much information is included in these chapters that is not specifically related to ore deposits. For just two examples, there is a map of the greenstone and gneiss belts of Canada and another showing how the Grenville fits into a paleotectonic reconstruction with the Oaxaca metamorphic complex and Sveconorwegian province. A final paper by R. W. Hutchinson (one of the world's leading experts in metallogenesis) summarizes the whole book and brings some sense of common theme to both the regional papers and part II on case histories, i.e., the importance of heated submarine exhalations as a function of tectonic setting for the genesis of most Precambrian ores. The recognition of the importance of submarine exhalations in ore deposition began in Europe with Schneiderhön in 1932, received support from Oftedahl in the late 1950's, became firmly adopted in Japan in the 1960's, was introduced in Canada by the Australian R. L. Stanton in the late 1950's, and only achieved some degree of acceptance in the United States by the mid-1960's owing to writings of Charles A. Anderson after his visits to the Miocene Kuroko ores of Japan. Models built especially on Kuroko deposits of Japan and the metal-rich brines of the Red Sea confirmed that the mineralizing fluid was evolved seawater. Thus, although all people working in this area found the active hydrothermal jets at 21°N on the East Pacific Rise to be exciting, exhalations were expected by researchers on ore genesis more than a decade before their discovery. It is a case of a modern feature being predicted from the fossil record, and Canadian scientists played a full role in this development.

Part II, comprising 17 case histories, was a mild disappointment to me, although it does help support the contention, in the final chapter, that submarine emanations are a key feature. The Geco base-metal massive-sulfide deposit (paper 10) is a world-class ore deposit that is described by R. G. Friesen et al., but the giant Kidd Creek deposit does not have a paper even though it has one of the most spectacular case histories in the use of genetic models and airborne geophysics in its discovery. It also is the world's largest producer of silver, Canada's leading producer of four other commodities, and will produce as much copper as a medium-sized porphyry-copper deposit (at an ecological 3 to 4 times the grade of porphyry coppers). Probably only Broken Hill, Australia, is a bigger zinc deposit. The giant Sudbury feature and its famous nickel deposits do not have a chapter either. The huge sediment-hosted Sullivan massive sulfide in the Purcell Supergroup of British Columbia has a chapter, but the huge Coeur d'Alene Pb-Zn-Ag vein deposit (which was once the world's largest silver producer) does not, even though it is just across the Canadian border in the United States and is hosted in the correlative Belt Supergroup. The reasoning for these kinds of omissions is given in the preface:

> Many important Precambrian sulphide deposits are not considered in the volume. Absent are those that have been extensively studied and for which thorough descriptions and up-to-date genetic interpretations have recently been published. Specifically included are newly discovered deposits and older ones for which only limited or out-dated information has been available.

An excellent example of a previously undescribed world-class deposit is the chapter on the Crandon Zn-Cu deposit in northern Wisconsin by E. R. May and P. G. Schmidt. Furthermore, the airborne geophysical techniques of aeromagnetics and electromagnetics played a key role in discovery of the extent of the metavolcanic belt and the Crandon deposit itself. D. J. Robinson and R. W. Hutchinson propose a novel and controversial volcanogenic-exhalative origin for the nickel-rich massive sulfide deposit at Redstone, Timmins, Ontario. The book should also be of interest to investigators of the deep-sea polymetallic deposits for comparison and model building. So although the book does not furnish "one-stop shopping" on descriptions of Precambrian ore deposits of Canada, it is the only or the best source on a number of them. It is sufficiently comprehensive so that it will lead readers to other references on key deposits which may not be adequately discussed. At $57, probably not many geophysicists will want the book for their personal libraries, but they should make sure that their institution has it, and taking a look through it would be very worthwhile. I recommend beginning with the summary chapter at the end.

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Geomagnetism of Baked Clays and Recent Sediments

K. M. Creer, P. Tucholka, and C. E. Barton (Eds.), Elsevier, New York, xv + 324 pp., 1983, $53.25.

Reviewed by Edward A. Mankinen

This book is an outgrowth of the symposium entitled "Time Scales of Geomagnetic Secular Variations," which was held at the 4th Assembly of the International Association of Geomagnetism and Aeronomy (Edinburgh, U.K., August 1981). The volume includes many of the papers presented, which described paleomagnetic results from both archeologic materials and Holocene geologic deposits, as well as contributions solicited from other researchers in the fields of archeomagnetism and paleomagnetism. In a remarkably short time after the conclusion of the symposium the editors were able to elicit, edit, and assemble a large body of material from 40 individuals into a thoughtful, well-organized product.

The book is divided into four chapters; the individual contributions constitute sections within each chapter. A comprehensive reference list concludes each chapter. The first two chapters are the shortest and provide a background for the rest of the book by discussing the processes by which various materials become magnetized and the methods that can be used to determine their age. Discussed in chapter 1 is the acquisition of a thermoremanent magnetization (TRM) by baked clays, a detrital, or depositional, remanent magnetization (DRM) by unconsolidated sediment, and the processes by which these magnetizations are sometimes modified or destroyed. Also discussed is the lesser-known but archeologically important shear remanent magnetization (SRM), which is acquired when mud is thrown into a mold during the manufacture of adobe bricks. Topics covered in chapter 2 include a description of palynologic correlation as a method of relative dating, the application of radiocarbon dating to sediment, tree ring and varve chronologies, sediment-dating methods using radioisotopes other than ^{14}C, and possible applications of the thermoluminescence (TL) dating method to both baked clays and sediment. Although they are fairly brief, the individual sections are well referenced and generally provide the reader with a sense of the capabilities and limitations of each method. Particularly welcome is a discussion of the sources of error in radiocarbon dating, which serves as a reminder that analytically precise ages do not necessarily guarantee geologic accuracy.

Chapter 3, the longest in the book, is devoted to studies of archeologic materials. One of the main objectives of these studies has been to construct curves of geomagnetic secular variation so as to obtain information on the nature of the field and to use these reference curves as dating and correlation tools at other archeologic sites. For secular variation studies to achieve their full potential, they must include measurements of paleointensity as well as paleodirection, and so the beginning of this chapter is devoted to a discussion of archeointensity methods. The Thelliers' method of paleointensity determination, which is a mainstay in paleomagnetic research, encounters special problems when it is applied to archeologic materials, and therefore the reliability of some of the earlier intensity results is not known. The situation, however, is not so bleak as some of the discussion may imply, and newer methods have been devised to overcome some of the earlier difficulties. Various alternating-field demagnetization techniques that are currently being investigated seem to show some promise as well. The rest of the chapter describes the results of archeomagnetic investigations in different regions of the world. Not only are summaries of previously published work provided, but some new data and references to work in press are also included, which should ensure that this book will not rapidly become out of date. Although an enormous amount of work is required to construct the reference curves, much progress has been made in several of the regions discussed. Because so many archeomagnetic data are thus combined into a single source, the reader can easily obtain a good idea as to the current state of secular variation research and can readily see how well the reference curves agree between studies and over how wide an area some features can be correlated. This chapter will be of particular interest not only to archeomagnetists and paleomagnetists but also to other geologists studying the Holocene, who could benefit from the use of the secular variation records being developed. Although archeomagnetic studies are providing many details on past secular variation, each point on a reference curve is a geologically "instantaneous" reading of the geomagnetic field. Archeologic materials do, however, have the advantage of being able to provide accurate, absolute values of paleointensity. Lacustrine sediment, on the other hand, can provide essentially continuous records of secular variation but only relative paleointensities. Thus these two types of studies can be complementary, and chapter 4 describes the progress that is being made in the study of unconsolidated sediment from various environments. The editors begin this chapter with a brief description of coring devices and measurement procedures, followed by summaries of results from rapidly deposited sediment in Europe, North and South America, and Australia. The chapter concludes with a discussion of statistical methods of data analysis, including data smoothing, comparison of related records, and spectrum analysis.

Overall, I find little to criticize in this book. Preparation of the text as camera-ready copy probably contributed to its timely publication. However, it is also somewhat harder to read than if it had been typeset, particularly because many of the punctuation marks seem to have become faint and indistinct during the final reduction. Because a few of the figures may not be entirely clear to the uninitiated reader, the individual contributors might have paid more attention to the figure captions, although most of the figures are well prepared and effective. In general, the individual sections seem to be of appropriate length for the topics addressed. The text is well edited, and there are very few typographical errors and little remaining jargon, such as "seriation dating." The editors have also succeeded in their intention of having the volume ". . .read as a book rather than as a collection of papers." Students and professional geologists alike should find it a valuable reference work.

Edward A. Mankinen is with the Geologic Division, Branch of Isotope Geology, U.S. Geological Survey, Menlo Park, Calif.

EOS

Transactions, American Geophysical Union

The Weekly Newspaper of Geophysics

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Cover. Maps of the ionospheric electron density, ion temperature, electron temperature, and line-of-sight drift as a function of UT and altitude during the May 30, 1984, annular eclipse of the sun. The measurements were made by the Millstone Hill incoherent scatter radar, using a 46-m steerable antenna pointed southwest at an azimuth of 225° and an elevation of 15°. The intersection of the radar beam and center line of the eclipse was at 37°N, 78°W at an altitude of 300 km. At this location the eclipse was centered at 1641 UT. The electron density at 300 km decreases to 70% of its value before and after the eclipse, with the minimum occurring 30 minutes after the center of the eclipse. The ion temperature shows only a small change. The electron temperature shows a 750 K decrease centered on the eclipse time. The line-of-sight velocity shows a perturbation near the beginning of the eclipse. (Figure courtesy of J. M. Holt, Massachusetts Institute of Technology Haystack Observatory, Westford, Mass. See news item "1984 Solar Eclipse," contributed by J. E. Salah.)

Career and Family: Making It Work

AGU Fall Meeting
Wednesday, December 5
6:00-8:00 P.M.
Crystal Ballroom
San Franciscan Hotel

Connie Sancetta of Lamont-Doherty Geological Observatory will moderate a discussion of how best to balance active involvement in a career with having and raising children. Panelists will be Tanya Atwater (University of California, Santa Barbara), Suzanne Beski-Diehl (Michigan Technological University), Laurie Brown (University of Massachusetts) and Sylvia Garzoli (Lamont-Doherty Geological Observatory).

This program has been arranged by the AGU Education and Human Resources Committee. Refreshments will be available.

Classified

Seismologist/Northern Illinois University, Department of Geology. The Department of Geology seeks to fill a tenure track position in Geophysics at the rank of Assistant Professor beginning August 15, 1985. Candidates with postdoctoral experience in applied seismology and whose research will involve students in field programs are most desired. The successful candidate will be expected to participate in and enhance an aggressive research program, teach at both the graduate and undergraduate levels, and interact with faculty and students in geophysics, geology, geochemistry and hydrology.

The Department, which offers both the M.S. and Ph.D. degrees, is composed of 15 faculty active in a wide range of research programs. Pertinent equipment owned by the Department includes a minicomputer, several magnetometers and gravimeters, a seismometer and a marine seismic system. Applicants should send a letter of application, resume, statement of research interests, and the names of three references to: Chair, Geophysics Search Committee, Department of Geology, Northern Illinois University, DeKalb, IL 60115.

Application deadline is January 15, 1985.

Northern Illinois University is an equal opportunity/affirmative action employer.

Saint Louis University. The Department of Earth and Atmospheric Sciences invites applications for a tenure-track assistant professor position in geophysics effective for the fall of 1985. We seek an individual with broad interests who will complement active research programs in seismology and earth structure. Preference will be given to candidates who can teach existing courses in plate tectonics, geomagnetism and/or geoelectricity. The successful candidate must have a Ph.D. degree and will be expected to maintain an active research program, to teach geophysics courses at the undergraduate and graduate levels, and to supervise graduate student research. The application deadline is January 15, 1985. Applicants should send a curriculum vitae, a statement of research and teaching interest and the names of 4 professional references to:

Dr. Brian J. Mitchell, Chairman
Department of Earth and Atmospheric Sciences
Saint Louis University
PO Box 8099—Laclede Station
St. Louis, MO 63156.

Saint Louis University is an affirmative action/equal opportunity employer.

College of Geosciences/University of Oklahoma. Applications and nominations are invited for the position of Director of the School of Geology and Geophysics. The Director is expected to have a Ph.D. or equivalent, a strong, ongoing research program and administrative experience; industrial experience helpful; field of geological specialization open; to begin July 1, 1985; salary to be negotiated.

In 1986, the School will move into the new 300,000 sq. ft. Energy Center along with other elements of the College of Geosciences; the Oklahoma Geology Survey; and the School of Petroleum and Geological Engineering and the School of Chemical Engineering and Materials Sciences, both from the College of Engineering.

Applications with curriculum vitae, names and addresses of three references, and/or nominations should be sent to:

Francis G. Stehli, Dean
College of Geosciences
University of Oklahoma
601 Elm Street, Room 438C
Norman, OK 73019.

Consideration of applications will begin January 1, 1985.

The University of Oklahoma is an Equal Opportunity/Affirmative Action Employer.

Research Groundwater Hydrologist

Argonne National Laboratory's Geoscience and Engineering Group seeks a groundwater hydrologist to conduct innovative research and to assist in the assessment of groundwater problems related to energy technologies.

Considerable knowledge of groundwater transport processes and experience in the use and development of related numerical models are required. Experience in research on the relationships between field data and model results is desirable. Strong written and verbal skills are necessary. The levels of knowledge and skills required will typically have been acquired through advanced formal education and several years of relevant experience and have been documented in publications.

On-going studies related to the siting of high-level radioactive waste repositories provide a variety of challenging groundwater problems. Argonne offers excellent computing and support facilities which will provide the opportunity to initiate activities in basic or applied groundwater research motivated by other energy/environment concerns.

Responses should be directed to:
Rosalie L. Ballina,
Box EES-22537-80,
Argonne National Laboratory,
9700 South Cass Avenue,
Argonne, IL 60439

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Hydrologist. Monterey, California. $1,887 to $2,298 per month plus benefits. Requires BS in Hydrology, computer programming skills and three years' experience. Apply by 5:00 p.m. November 15, 1984. Send resume to Monterey Peninsula Water Management District, P.O. Box 85, Monterey, California 93940. Call 408-649-4866 for job flyer.

EOE.

Texas Tech University/Geophysicist or Clastic Sedimentologist. The Department of Geosciences at Texas Tech University seeks applications for a tenure track position in the fields of geophysics or clastic sedimentology to begin August 1985. Rank and salary will be commensurate with qualifications. The Ph.D. is required. Entry-level applicants will be given preference. The primary responsibility would be to teach both graduate and undergraduate courses in geophysics or depositional systems and sedimentology, his/her specialty, and introductory geology. The person will be expected to initiate a research program and to direct MS and Ph.D. graduate students. Send a letter of application with complete curriculum vitae and names of three references to Dr. Alonzo D. Jacka, Chairman of Geosciences, P.O. Box 4109, TTU, Lubbock, TX 79409.

Texas Tech is an equal opportunity/affirmative action employer. Applications deadline: January 31, 1985.

Seismologist/University of Utah. The Department of Geology and Geophysics at the University of Utah seeks applicants for a tenure track faculty position in seismology at the assistant to associate professor level. Applicants with backgrounds and specialties in seismic imaging, seismic reflection or theoretical seismology will be given preference. The individual will be expected to teach undergraduate and graduate courses and to pursue an active research program with graduate students. A seismic imaging laboratory with a VAX 11/750, FPS array processor, plotters, and processing and synthetic seismogram software is available to the successful candidate. Current research in seismology includes: earthquake research utilizing a PDP 11–70 computer; monitoring of the Intermountain seismic belt by an 85 station telemetered network utilizing an online PDP 11–34 computer; major experiments in seismic refraction and reflection profiling for crustal structure; and allied research in tectonophysics. The opportunity exists to participate with several other faculty in an integrated program of tectonics, seismology and sedimentology directed toward crustal studies and petroleum exploration. The geophysics component of the department has active research and teaching programs in electrical and electromagnetic methods, thermal properties of the earth, potential fields, and seismology. The department has close associations with the numerical analysis and data processing groups in computer science, electrical engineering and mathematics. The closing date for applications is December 31, 1984, and the appointment date is September 15, 1985. A Ph.D. is required for this position. Applicants should submit a vita, transcripts, a letter describing his/her research and teaching goals and names of five persons for reference. Qualified persons should send their applications to William P. Nash, Chairman, Department of Geology and Geophysics, University of Utah, Salt Lake City, Utah 84112–1183.

The University of Utah is an equal opportunity/affirmative action employer.

Faculty Positions in Geochemistry and in Neotectonics. The State University of New York at Binghamton invites applications for tenure track positions in these two areas beginning August, 1985. The appointments will be at the assistant or junior associate professor level and will require completion of the PhD prior to this date. The candidates must demonstrate potential to develop a productive research program as well as teach at the undergraduate and graduate levels.

The geochemist should have primary interest in some aspect of low temperature geochemistry. The neotectonist should have some interest and experience in study of sedimentologic and/or geomorphic processes and products as well as tectonic ones. Applicants should send a resume and names of three persons who can be contacted for references to: J.R. Beerbower, Department of Geological Sciences and Environmental Studies, State University of New York, Binghamton, NY 13901.

The State University of New York is an affirmative action/equal opportunity employer. The closing date for this position is 15 December 1984.

Visiting Appointments/Princeton University. A limited number of one-year visiting appointments, with the possibility of renewal, are available on a competitive basis for new and established Ph.D.'s to carry out research in dynamics and predictability of the atmosphere and oceans, climatology, atmospheric and oceanic chemistry, basic geophysical fluid dynamics, and solid earth geophysics. Successful applicants will have access to the facilities of the Geophysical Fluid Dynamics Laboratory/NOAA. Information and application forms can be obtained from: Chairman, Visiting Scientist Selection Committee, Geophysical Fluid Dynamics Program, Princeton University, P.O. Box 308, Princeton, New Jersey 08542.

Princeton University is an equal opportunity employer—M/F.

Postdoctoral Position/Oregon State University. Research Associate (postdoctoral), at Oregon State University's Cooperative Institute for Marine Resources Studies. Expertise in physiological and chemical ecology with interest in interactions of hydrothermal vent fauna with the unique biogeochemical properties of their environment. Familiarity with state-of-the-art analytical techniques (GC, GC/MS, HPLC) highly desirable. One (1) year, renewable for a second year subject to approval. Send C.V., names and addresses of three (3) references by 30 November 1984 to Director, CIMRS, Hatfield Marine Science Center, Newport, Oregon 97365.

OREGON STATE UNIVERSITY, AN AFFIRMATIVE ACTION/EQUAL OPPORTUNITY EMPLOYER, COMPLIES WITH SECTION 503 OF THE REHABILITATION ACT OF 1973.

Harvard University/Faculty Position in Petrology. The Department of Geological Sciences, Harvard University, invites applications for a faculty position in petrology. We are interested in persons concerned with the mineralogy and the major and/or trace element chemistry of metamorphic and igneous rocks in relation to their geologic and tectonic setting. Experience with modern methods for the study of natural rocks, both in laboratory and in the field, is essential. The successful applicant must have the Ph.D. degree by the time of appointment and demonstrated capabilities to conduct original research and to teach both undergraduate and graduate students. The appointment will be made at the Assistant or Associate Professor level depending on qualifications and experience. The 1984/85 salary ranges are $26,600—$28,200 for Assistant Professor and $30,000—$33,600 for Associate Professor. Appointments are made for an initial term of up to five years. Interested applicants should send vita, bibliography, and names of three references to:

Professor Adam M. Dziewonski
Harvard University
Hoffman Laboratory
20 Oxford Street
Cambridge, MA 02138.

Harvard University is an equal opportunity/affirmative action employer. Women and minorities are encouraged to apply.

DEAN
COLLEGE OF ENGINEERING
Colorado State University

Nominations and applications are invited for the position of Dean of the College of Engineering. Colorado State University is a comprehensive research university of 18,000 students, located 60 miles north of Denver. The College of Engineering has 1,400 undergraduate and 400 graduate students in the departments of Agricultural and Chemical, Civil, Electrical, and Mechanical Engineering, Atmospheric Science and the Engineering Science major. Each department offers MS and PhD programs. The College has 110 faculty who annually conduct about $15M of contract and grant research in support of the graduate programs in the five departments. A new computer-assisted engineering center serves the entire College. Applicants must have a doctorate, be tenurable in one of the departments, have a distinguished record of publications in scholarly journals, experience in contract/grant activities, and have substantial teaching and administrative experience. The Dean is expected to provide leadership for the undergraduate and graduate teaching programs as well as the research activities. Salary will be commensurate with comparable positions at other land grant institutions. Applicants should send a letter of intent, a résumé and also ensure that five letters of reference are sent to Dr. Robert D. Phemister, Dean's Search Committee, Office of the Dean, College of Veterinary Medicine and Biomedical Sciences, Colorado State University, Fort Collins, CO 80523. Applications must be received by January 15, 1985.

Colorado State University is a EEO/AA employer. Equal Opportunity office: 314 Student Services Building, Colorado State University, Fort Collins, CO 80523.

South Dakota School of Mines and Technology. The Department of Geology and Geological Engineering is seeking applicants for a full-time tenure track position in geological engineering beginning fall 1985. Applicants should have a Ph.D. degree or commensurate experience including "Registration" in geotechnical or petroleum engineering or geohydrology and will be expected to teach at both undergraduate and graduate levels as well as conduct an active research program in their field of specialization.

The Department has an undergraduate enrollment of 200 majors and a graduate enrollment of 60. Field applications are emphasized. Interested persons should send a resume and three letters of recommendation to Alvis Lisenbee, Department of Geology/Geological Engineering, South Dakota School of Mines and Technology, Rapid City, SD 57701.

Deadline for applications is February 1, 1985.

SDSM&T is an equal opportunity employer.

Graduate Fellowships/University of Oklahoma. The School of Geology and Geophysics offers fellowships for Ph.D. study in each of the following broad disciplines: (1) origin, ascent, and fractionation trends in magmas and associated ore deposits; (2) formation and tectonic evolution of continental lithosphere, including geophysical properties and structures of the upper crust; and (3) sedimentary processes, including organic and inorganic diagenesis, evolution of hydrocarbons, and correlation using biostratigraphic methods. Average fellowship stipends are for $10,000/9 month and are renewable annually on a competitive basis. Fellowship awards include a waiver of out-of-state tuition and fees.

The School of Geology and Geophysics presently consists of 19 full-time faculty. Research facilities in the school include a stable isotope laboratory; organic geochemistry laboratory; computer automated X-ray diffraction and fluorescence equipment; atomic absorption and neutron activation analysis equipment; scanning electron microscope with energy dispersive analyzer; transmission electron microscope; fission-track dating laboratory; fluid inclusion microthermometry laboratory; 2 kb hydrothermal laboratory for phase equilibrium experiments; high-pressure rock mechanics laboratory; paleomagnetic laboratory with a cryogenic magnetometer and thermal and AF demagnetization apparatus; 24-, 48-, and 192-channel digital seismic recording systems; a VAX 11–785 computer with high-resolution graphics and image-display terminals, with seismic and image processing software; and a 84,000 volume geology and geophysics library located in the department.

For further information on faculty and active research projects, contact: Kevin Crowley, School of Geology and Geophysics, University of Oklahoma, 830 Van Vleet Oval, Norman, OK 73019.

Sedimentary Petrologist/Wright State University. The Department of Geological Sciences invites applications for a tenure track position in sedimentary petrology, at the assistant professor level beginning September 1, 1985. Candidates must have an interest in carbonate rocks and basin analysis. Preference will be given to people capable of teaching introductory paleontology. The Department has a large M.S. program and wishes to expand their sedimentary petrology group. Applicants should expect to complete all requirements for the Ph.D. in geological sciences or related field by September 1, 1985. Send resume and three letters of reference to Chairman, Search Committee, Department of Geological Sciences, 260 Brehm Laboratory, Wright State University, Dayton, Ohio 45435. Closing date for applications is January 15, 1985.

Wright State University is an equal opportunity/affirmative action employer.

A WORKSHOP ON ODP DRILLING IN THE N.E. PACIFIC

INPAC (International N.E. Pacific Activities Consortium) announces a workshop to further define a drilling program in the N.E. Pacific using the new ODP drilling ship SEDCO/BP 471, which is scheduled to be in the region in summer 1990. The workshop will take place at the School of Oceanography, University of Washington on February 20–22, 1985. The three-fold focus of the proposed integrated, multi-disciplinary drilling program will include: 1) ridge crest processes on the Juan de Fuca Ridge, 2) convergent margin processes off the Washington, Oregon, and British Columbia coasts, and 3) paleo-oceanography of the N.E. Pacific. The purpose of the workshop will be to further define major scientific problems that can be addressed by drilling, to identify possible drill sites, to present the results of relevant on-going scientific programs in the area, and to organize the data gathering and synthesis necessary to write a comprehensive drilling proposal to JOIDES. The two and one half day workshop is open to all parties who have an interest in the drilling program in the N.E. Pacific. Interested parties should write to the INPAC Committee, c/o Paul Johnson, School of Oceanography WB-10, University of Washington, Seattle, WA 98195, prior to 1 December 1984.

Seismologist. The Department of Geological Sciences at the University of Texas at El Paso anticipates a tenure track position for a seismologist beginning September 1, 1985. Applications should have a strong commitment to research and interests which complement our ongoing efforts in lithospheric seismology. Our geophysics group is generally well equipped in terms of field, laboratory, and computational facilities. There are three geophysicists in the Department of Geological Sciences with supporting faculty in the Physics Department. The graduate student enrollment in the program is 15–20. A doctorate is required, and the appointment will be at the Assistant Professor level. The salary level will be competitive. Send resume and three letters of reference to: Dr. G.R. Keller, Chairman, Department of Geological Sciences, University of Texas at El Paso, El Paso, Texas 79968–0555. Closing date for applications is January 31, 1985.

The University is an equal employment opportunity/affirmative action employer.

Physical Oceanographers. The Physical Oceanography Branch of the U.S. Naval Oceanographic Office seeks full-time Oceanographers for the study of the effects of oceanic current and thermal/density structure on undersea systems using data collected from various platforms for a variety of projects. The projects involve the collection, analysis and reporting of physical oceanographic data directly applicable to relevant Navy environmental requirements. Up to 50% field duty may be required.

Multiple vacancies at the GS-7, 9 and 11 levels are available depending upon qualifications and experience and will remain open until filled. Salary range: $17,221 to $35,139.

Please contact (for required forms): Debra Staples, #N00–72(84), Commercial 601-688-5720, Autovon 485-5720, or FTS 494-5720, U.S. Naval Oceanographic Office, Management & Personnel Division, Personnel Operations Branch, Code 4320, Bay St. Louis, NSTL, Mississippi 39522.

University of Utah: Structural Geology/Tectonics/Tectonophysics. The Department of Geology and Geophysics at the University of Utah seeks applications for a tenure track position in structural geology, tectonics or tectonophysics. It is anticipated that this position will be filled at the assistant professor level, but applications by more senior persons will be considered. The position requires a Ph.D. with emphasis in structural geology, regional tectonics or tectonophysics. The new faculty member will have the opportunity to teach in the area of his or her specialty and may also be assigned introductory level courses. The successful candidate will be expected to establish a vigorous research program involving graduate students. The person who fills this position will join an active program in structural geology and tectonics that includes both field projects and integrated geology/geophysics and mechanics/fluid chemistry studies of structures in the western Cordillera. There is an excellent opportunity to collaborate with other faculty in structural geology, sedimentology, geophysics, geochemistry and petrology. A vita, copies of publications, names of three persons that may provide references, and a letter outlining the candidate's research and teaching interests should be sent to Dr. William P. Nash, Chairman, Department of Geology and Geophysics, University of Utah, Salt Lake City, Utah 84112–1183. Deadline for receipt of applications is December 31, 1984 with the appointment starting in September 1985

The University of Utah is an equal opportunity/affirmative action employer.

Postdoctoral Fellowships
at the
Woods Hole Oceanographic Institution
OCEAN SCIENCE and ENGINEERING

Applications are invited from new or recent doctorates in science or engineering with interests in physical oceanography, marine chemistry, marine geology and geophysics, biological oceanography, or oceanographic engineering. Recipients of awards are selected on a competitive basis, with primary emphasis placed on research promise.

Fellowships are awarded for one year with a stipend of $23,100 plus group health insurance and a modest research budget. Recipients are encouraged to pursue their own research interests independently or in association with resident staff. Completed applications must be received by *15 January 1985* for 1985-86 awards. Awards will be announced by 1 March. Write for application forms to:

Dean of Graduate Studies
P.O. Box 8
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543
Equal Opportunity Affirmative Action Institution

Seismologist/Ohio State University. The Department of Geology and Mineralogy, The Ohio State University, invites applications for a tenure-track position for a seismologist with research interests in crustal geology and tectonics. The successful applicant must be prepared to assist in teaching exploration geophysics courses, advanced topics in his/her speciality, conduct research, and supervise graduate students. Postdoctoral or industrial experience is desirable. Rank and salary commensurate with experience and research record. Please send applications or nominations to:

Dr. Ralph R.B. von Frese
Chairman, Search Committee
Department of Geology and Mineralogy
The Ohio State University
Columbus, OH 43210.
Telephone: 614-422-5635 or 422-7221.

Applications should include a resume, a statement of research interests and three persons whom we may contact for recommendations. The closing date for applications is December 1, 1984; appointments will be effective no later than October 1, 1985. Additional information can be obtained by writing or calling the chairman of the search committee.

The Ohio State University is an equal opportunity/affirmative action employer.

Cosmochemistry Faculty Position/University of Arizona. The Department of Planetary Sciences and the Lunar and Planetary Laboratory invite applications in a continued search to fill a state-funded, tenure track position in cosmochemistry. The area of specialization within Cosmochemistry is open. The appointment involves research, teaching, and the supervision of graduate students. The successful candidate will be either at a junior level with extraordinary promise of scientific accomplishment, as well as the potential for developing substantial leadership capabilities and an international scientific reputation, or will be at a senior level having already demonstrated these qualities. Applications, including a resume and the names and addresses of four individuals who could serve as professional references, should be sent, by December 31, 1984, to Professor Eugene H. Levy, Head, Department of Planetary Sciences, University of Arizona, Tucson, AZ 85721.

The University is an equal opportunity/affirmative action employee.

AGU STUDENT
MEMBERS :
Special 50% discount
on "paid & carried"
books at the AGU
Fall Meeting. Ask
at booth for details.

Professor (Research)/Stanford University/Plasma Physics, EM Waves, Space Physics. We are seeking a senior person who has demonstrated scientific, managerial, and leadership qualifications in one or more of the following disciplines: Space Plasma Physics, electromagnetic waves, and solar-terrestrial physics. We expect the successful candidate to have established an outstanding reputation documentable through professional writings or other evidence of personal technical creativity, letters of reference from recognized research leaders in the disciplines mentioned above, and/or awards and other recognition from appropriate professional societies.

It is expected that this individual will develop a research program in one of the disciplines given above working in coordination with ongoing programs within the STAR Laboratory and, possibly, with other activities within the Stanford Center for Space Science and Astrophysics. It is expected that this individual will have a strong background in experimental techniques, either in the laboratory or in the field, including the environment of space; experimental activities in either laboratory or space plasma physics would be regarded as good qualifications. However, close association with theoretical developments in plasma physics and/or electromagnetic theory will clearly be desired. It is also expected that the individual will have a demonstrated capability for securing federal or other research grant support, or be deemed by the selection committee of being capable of securing such funds.

It is anticipated that the person chosen will devote the major part of his or her time to research activities. However, there is an opportunity for participation in academic responsibilities of the Electrical Engineering Department, including, when time permits, teaching graduate and undergraduate classes, serving on various committees of the department, School of Engineering, and the university. It is expected that the person chosen will participate actively in the training of graduate students.

The Chairman of the selection committee for this position is *Professor Robert A. Helliwell, Professor of Electrical Engineering, Space, Telecommunications, and Radioscience Laboratory, Stanford University, Stanford, California 94305.* Other members of the selection committee include Professor P.M. Banks, Professor R.N. Bracewell, Professor L.R.O. Storey, and Professor L. Tyler.

Application deadline is November 15, 1984.

High Altitude Observatory Scientific Visitor Program/NCAR. Scientific visitor appointments at the High Altitude Observatory are available for new and established Ph.D's for up to one year to carry out research in solar physics, solar-terrestrial physics, and related subjects. Applicants should provide a curriculum vitae, including education, work experience, publications, the names of three scientists familiar with their work, and a statement of their research plans. Applications must be received by 15 January 1985 and they should be sent to: The HAO Visitor Committee, High Altitude Observatory, National Center for Atmospheric Research, P.O. Box 3000, Boulder, Colorado 80307–3000.

NCAR is an Equal Opportunity/Affirmative Action Employer.

Yale University/Solid Earth Geophysics. The Department of Geology and Geophysics is soliciting applications for a junior faculty position in solid-earth geophysics to begin in the academic year 1985–1986. Areas of interest to the department include seismology, exploration geophysics, mechanical and physical properties of rocks and minerals, geomagnetism, tectonophysics, and geodesy. Curriculum vitae, publications and the names of three or more referees should be sent by December 1, 1984 to Karl K. Turekian, Chairman, Department of Geology and Geophysics, Yale University, Box 6666, New Haven, CT 06511.

Yale University is an equal opportunity/affirmative action employer and encourages applications from all qualified scientists.

Sedimentologist-Oceanographer/Texas A&M University. Applications are invited for a tenure track faculty position in the general field of marine sedimentology. The position will involve graduate level teaching and supervision of graduate student research. The successful applicant will have demonstrated excellence in or a strong potential for independent research in the field of marine sedimentation. The position is available beginning September 1, 1985. Salary and rank will be commensurate with experience and qualifications. Applicants are invited to submit curricula vita, copies of publications, names of three persons who may serve as references, and a letter outlining the applicant's teaching and research interests by December 31, 1984, to Robert O. Reid, Distinguished Professor and Head, Department of Oceanography, Texas A&M University, College Station, Texas 77843.

Texas A&M University is an affirmative action/equal opportunity employee.

University of Arizona/Groundwater Hydrologist. The University of Arizona, College of Engineering, Department of Hydrology and Water Resources, invites applications for a tenure track faculty position at the Assistant or Associate Professor level in groundwater hydrology. Applicants should have a strong background in hydrogeology, groundwater hydraulics, contaminant transport, and groundwater modeling. The position will involve teaching graduate and undergraduate classes and developing a strong research program in one or more of the above areas. Interested persons should send an up-to-date resume and the names of at least three references to:

Dr. Shlomo P. Neuman
Department of Hydrology and Water Resources
University of Arizona
Tucson, Arizona 85721

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Faculty Position in Applied Geophysics or Structural Geology. The Department of Earth Sciences, University of New Orleans, invites applications for a permanent faculty position commencing August, 1985 in APPLIED GEOPHYSICS or STRUCTURAL GEOLOGY.

The University of New Orleans, located on the south shore of Lake Pontchartrain has 14,00 undergraduate and 2,500 graduate students. The Earth Sciences Department currently has a staff of 11 full-time and four part-time faculty and approximately 150 undergraduate geology majors and 50 master's candidates.

The appointee will be expected to teach graduate and undergraduate courses in geophysics-structural geology and general geology, conduct a program of research and supervise theses. The position will be at the assistant professor level. Applications are encouraged from individuals with industrial experience. The Ph.D. degree is required.

Applicants should send a letter outlining interest in position, complete resume, and three letters of recommendation to:

Dr. Louis A. Fernandez, Chairman
Department of Earth Sciences
University of New Orleans
New Orleans, LA 70148

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SUPERVISORY OCEANOGRAPHER DIVISION LEADER

NOAA's Pacific Marine Environmental Laboratory is seeking qualified candidates for the position of Division Leader, Marine Resources Research Division. The Division is located at the Hatfield Marine Sciences Center, Newport, Oregon and is engaged in multidisciplinary research into deep seafloor exchange processes. Current activities include research into the effects of hydrothermal venting, oceanic crustal tectonic processes, seafloor heat flux, and particle transport in the benthic boundary layer. The Division Leader has responsibility for program planning and budgeting, technical supervision of MRRD staff and liaison with other NOAA components. The Division Leader has primary obligation for leading the MRRD research program, but there is adequate opportunity to conduct individual research.

Candidates should have at least a PhD in physical oceanography and/or geology or related physical sciences. Candidates must have at least three years of professional research experience of which at least one year must have been comparable to the GS-14 level in the Federal service. Candidates must have experience in sea floor processes research including biological, chemical, geological or physical oceanography or they will not be found qualified for this position. Also, candidates must demonstrate that they have the: ability to conduct sea floor processes research; ability to conduct independent research; ability to develop, implement and monitor scientific research programs; ability to supervise a scientific/technical staff; ability to ensure fiscal accountability through management of program funds within budget constraints; ability to make technical presentations, both orally and in writing, and; ability to implement an effective Affirmative Action (EEO) program. Applicants are asked to describe their experience in each of the above seven factors. These responses should be considered as attachments to the basic application form. The salary ranges from $50,495 to $65,642 per year. This position is in the Federal Competitive Service; however, persons with no previous Federal service may apply. Applicants should refer to announcement number PMEL/WASC 84-292 (PM) when submitting applications (SF-171, "Personal Qualifications Statement", available at most Federal agencies) to:

NOAA, WASC, Personnel Division
7600 Sand Point Way NE
Seattle, WA 98115

by November 30, 1984. For further application information call Pete Macias at 206-526-6048. For further details on duties contact Dr. E. N. Bernard, Director, PMEL at 206-526-6800.

Professor/Chairperson: The University of Utah. The University of Utah Department of Civil Engineering is seeking applicants for the position of Professor and Chairperson. Applicants with experience in an academic environment, strong research credentials and proven leadership capabilities are urged to apply. Candidates are sought who have a proven interest in developing research and have demonstrated ability to generate research grants. The position offers professional challenge with potential for future growth, and a unique opportunity to faculty with commitment to scholarly research and education. The appointment is to begin July 1, 1985 and the closing date for the receipt of applications is January 15, 1985, or until the position is filled. Please submit a complete resume and at least three professional references (include addresses and telephone numbers) to:

Dr. J.D. Seader
Chairman, Search Committee
Department of Chemical Engineering
University of Utah
Salt Lake City, UT 84112
801-581-6916.

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Geochemistry. The University of California, Davis will fill a permanent, tenure track, faculty position at the assistant professor level beginning Fall, 1985. Candidates having interests in isotope geochemistry and/or the geochemistry of economic deposits are especially encouraged to apply but other specialties in geochemistry will be considered. A PhD degree is required. Responsibilities include teaching at the undergraduate and graduate levels, and research in geochemistry.

Applicants should submit complete vita, a statement of research and teaching interests and the names of three referees. Deadline for application is January 15, 1985. Inquiries and applications should be directed to: Dr Howard W. Day, Department of Geology, University of California, Davis, CA 95616.

The University of California is an equal opportunity/affirmative action employer.

University of Wisconsin—Madison. The Department of Geology and Geophysics invites applications for an anticipated tenure track position at the assistant professor level in applied geomorphology and/or hydrogeology commencing in August 1985. The applicant should be committed to developing a strong research program as well as teaching undergraduate courses in some aspects of engineering and environmental geology. The Ph.D. is required. Applicants with course work in engineering and an interest in the field application of geologic principles are especially encouraged to apply. Send letter of application outlining your professional goals, transcripts, resume, copies of publications, and three letters of reference to Dr. Mary P. Anderson, Department of Geology and Geophysics, Weeks Hall, University of Wisconsin, Madison, WI 53706. Closing date is January 1, 1985.

The University of Wisconsin is an equal opportunity/affirmative action employee.

University of Wyoming/Department of Geology and Geophysics. The Department of Geology and Geophysics encourages applications from students interested in pursuing graduate research in the fields of igneous and metamorphic petrology and geochemistry. Current research topics, involving field and laboratory studies, include: island arc and continental volcanics, petrogenesis of granitic and anorthositic rocks, evolution of the Archean crust, petrogenesis of mylonitic rocks, and geothermometry and geobarometry as applied to the evolution of orogenic terranes. Facilities include: an analytical geochemical lab for whole-rock and trace element analysis, a fully automated CAMECA microprobe, two JOEL scanning electron microscopes, a thermal ionization mass spectrometer for analyzing Rb-Sr, Sm-Nd, and U-Th-Pb isotopes, a microthermometry lab, and an experimental petrology lab. Applicants should contact:

Petrology/Geochemistry Program
Department of Geology and Geophysics
PO Box 3006, University Station
University of Wyoming
Laramie, WY 82071.

Faculty Position in Geophysics Frankfurt University (FRG)

The Institute of Meteorology and Geophysics at the Johann Wolfgang Goethe-University in Frankfurt (Federal Republic of Germany) has a vacancy at the C3-Professor level. The position is tenured. The appointee will be expected to teach courses in applied geophysics at the undergraduate and graduate levels (in German). Research experience in the area of geoelectric methods would be desirable but not condition. Candidates with other areas of research interest will also be considered.

Application with curriculum vitae, certificates on academic degrees, list of publications and teaching experience should be submitted to the President, Universität Frankfurt, Senckenberganlage 31, 6000 Frankfurt a. M. by November 15, 1984.

Meetings

Announcements

Chapman Conference on Ion Acceleration

Call for Papers

June 3–7, 1985 Chapman Conference on Ion Acceleration in the Magnetosphere and Ionosphere, Wellesley, Mass. Sponsor: AGU. (Ion Acceleration Meeting, American Geophysical Union, 2000 Florida Avenue, N. W., Washington, D. C. 20009; tel.: 202-462-6903 or toll free 800-424-2488.)

The deadline for submission of abstracts is February 4, 1985.

Recent satellite and rocket data on particle distributions indicate that ions in the ionosphere and magnetosphere are subjected to a variety of energization processes. Wave-particle interactions, electrostatic double layers and shocks, Alfvén waves, anomalous resistivity, E × B drift, magnetic inhomogeneities, and other ideas have been proposed as viable mechanisms responsible for the energization of ions. For the most part, however, coherent theories capable of providing definitive descriptions of the observed ion acceleration phenomena have not yet emerged.

The purpose of this conference is to bring together experimentalists and theoreticians engaged in the study of various aspects of ion energization processes in the magnetosphere, to promote interchange of ideas among these active researchers, and to attempt to achieve some basic understanding of these interesting and complex space plasma phenomena.

Format and Abstracts. Aside from several invited review talks, this conference will consist mainly of contributed oral and poster papers. Topics to be covered by the conference include ion acceleration processes at high latitudes (auroral arc, polar cap, polar cusp, etc.), ion acceleration processes in the plasma sheet and its boundary layer, ion acceleration processes in the equatorial region (geosynchronous orbit, ring current, etc.), ion acceleration processes in active ionospheric and magnetospheric experiments (charged beams, gas releases, etc.), ion acceleration in laboratory plasmas (space simulation and scaled experiments), microscopic ion acceleration processes (wave-particle interactions, double layers, stochastic heating, etc.), and macroscopic acceleration processes (adiabatic processes, shocks, etc.).

All interested in attending and in receiving later information circulars should write to the address given above. For more information on the scientific program, contact Tom Chang, Center for Space Research, Room 37–261, Massachusetts Institute of Technology, Cambridge, MA 02139; telephone: 617-253-7523. Abstracts should follow the standard AGU format, as published in *Eos*, August 14, 1984. There will be no abstract charge. Authors are requested to indicate their preference for the mode of presentation (oral or poster), although papers may be assigned to either mode depending on the overall plan of the conference program.

Program Committee. R. Arnoldy, M. Ashour-Abdalla, R. Bostrom, C. G. Fälthammar, L. Frank, H. R. Balsiger, D. Gorney, G. Haerendel, D. Hardy, J. P. Heppner, B. K. Hulquist, D. Klumpar, R. Lysak, F. Mozer, H. Okuda, R. Olsen, S. Ossakow, R. Schunk, E. G. Shelley, E. Wescott, D. Williams, O. Winningham, and D. Young, and the coconvenors, Tom Chang, J. R. Jasperse, R. G. Johnson, P. M. Kintner, and M. Schulz.

Student Travel. Limited funding will be available to support student travel expenses to the conference. To apply, call the AGU Meetings Department at the number given above and ask to be sent a travel grant application. The awardees will be selected by AGU in conjunction with the coconvenors. Deadline for travel applications is January 7, 1985.

JECSS Workshop

May 13–18, 1985 Third JECSS (Japan and East China Seas Study) Workshop, Tsukuba Univ., Japan. Sponsors: Japan Marine Science and Technology Center, Oceanographical Society of Japan, Japanese-French Oceanographical Society, AGU. (Takashi Ichiye, Dept. of Oceanography, Texas A & M Univ., College Station, TX 77843.)

The deadline for the submission of one-page abstracts is November 30, 1984.

The purposes of this workshop are to exchange research results in hydrography, circulation, physical and chemical properties, and sedimentology of the East Asian marginal seas and to plan cooperative programs for field experiments and modeling. Papers in the topics listed are invited and will be arranged into discussion groups and presentations around the lectures of the invited speakers.

Coral Reefs

May 27–June 1, 1985 Fifth International Coral Reef Congress, Tahiti, French Polynesia. (Organizing Committee, Coral Reef Congress, B.P. 562 Papeete, Tahiti, French Polynesia.)

The submission deadline for the 300-word abstracts is December 1, 1984. Abstracts should be submitted in both French and English.

The congress will consist of two principal parts. The first is a symposium entitled "Late Quaternary and Present Sea-Level Changes: Magnitude, Causes, Future Applications." Papers for this symposium are being solicited on topics including global, regional, and local histories of sea level changes, measurement, modeling, and interpretation of such changes, correlation of changes with tectonic, climatic, and oceanographic changes, and prediction of near-future changes for application to a variety of problems, especially those relating to coral reefs. The second part is a seminar entitled "Reef Growth and Sea-Level Change: The Environmental Signature." This seminar, chaired by P. J. Davies, will deal with the identification of the sea level signature in reefs from varied environments, including the analysis of variations of fauna, diagenesis, isotopes, calcification, and sedimentology.

Hydraulics and Hydrology

Aug. 13–16, 1985 Hydraulics and Hydrology in the Small Computer Age, Orlando, Fla. Sponsor: Hydraulics Division, American Society of Civil Engineers. (William R. Waldrop, TVA Water Systems Development Branch, PO Drawer E, Norris, TN 37828; tel.: 615-632-4460.)

The submission deadline for one-page abstracts is December 1, 1984.

Papers are solicited for presentation in technical sessions on topics including computerized data acquisition systems in the laboratory and in the field, microcomputer software applications in hydraulics and hydrology, coastal and wetlands processes, groundwater hydrology, surface water hydraulics and hydrology, and hydropower development. Various special tours and exhibits are also planned.

Future AGU Meetings

Fall Meetings

Dec. 3–7, 1984, San Francisco, California.

Dec. 9–13, 1985, San Francisco, California. Abstracts due mid-September 1985.

Dec. 8–12, 1986, San Francisco, California.

Spring Meetings

May 27–31, 1985, Baltimore, Maryland. Abstracts due early March 1985.

May 19–23, 1986, Baltimore, Maryland.

Regional Meetings

Front Range Branch Hydrology Days, April 16–18, 1985, Fort Collins, Colorado. Abstracts due December 31, 1984 for professional hydrologists, February 15, 1985 for students; call for papers appeared in July 24, 1984 *Eos*.

Chapman Conferences

Solar Wind-Magnetosphere Coupling, February 12–15, 1985, Pasadena, California. Abstracts due November 1, 1984; call for papers appeared in July 10, 1984 *Eos*.

Ion Acceleration in the Ionosphere and Magnetosphere, June 3–7, 1985, Boston, Massachusetts. Abstracts due February 4, 1985; call for papers appears in this issue.

Magnetotail Physics, October 28–31, 1985, Laurel, Maryland.

The last Geophysical Year calendar ran October 23, 1984, in *Eos*.

GAP

Separates

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Electromagnetics

0720 Electromagnetic theory
ORTHOGONAL MAPPINGS OF TIME-HARMONIC ELECTROMAGNETIC FIELDS IN INHOMOGENEOUS (BI)ANISOTROPIC MEDIA
W. Suchy (Inst. Theoretical Physics, University of Düsseldorf, D-4 Düsseldorf 1, Fed. Rep. Germany), C. Altman and A. Schatzberg

One of the prerequisites for Lorentz' reciprocity theorem to hold in anisotropic media is the symmetry (or hermiticity) of the constitutive tensors for permittivity, permeability and conductivity. If they are not symmetric (or hermitian) usually another medium is introduced for the validity of the theorem. But if the medium is inhomogeneous and the non-symmetric (or non-hermitian) constitutive tensors obey certain symmetry requirements if compared at two different positions, then the theorem holds in the same medium. These symmetry requirements are stated using orthogonal mappings for the position vector, the electromagnetic field vectors, the constitutive tensors, the boundary conditions and Green's tensor. Various examples are given for uniaxial media, including cold magnetized plasmas. (Lorentz' reciprocity, constitutive tensors, inhomogeneous media)

Rad. Sci., Paper 4S1144.

0785 Tropospheric propagation
THEORETICAL PREDICTION OF THE OPERATIONAL CHARACTERISTICS OF A DOUBLE POLARIZED MICROWAVE COMMUNICATION SYSTEM
J.D. Vasiliopoulos (Electrical Engineering Department, National Technical University of Athens, Athens-147, Greece).

In this paper, a general analysis is proposed for the prediction of the operational characteristics of a double polarization microwave communication system where the dominant factor for degradation has been taken to be the rainfall. This analysis can be considered as an improved version of previous techniques dealing with the same subject. One of the features of the paper is the analytical examination of the spatial inhomogeneity of the rain medium as it affects the joint statistical analysis between rain attenuation and depolarization. (Rain propagation, microwave links).

Rad. Sci., Paper 4S1208.

Geochemistry

1429 Chemistry of bodies of water
MAJOR ION CHEMISTRY AND SENSITIVITY TO ACID PRECIPITATION OF SIERRA NEVADA LAKES
J.M. Melack, (Biological Sciences and Marine Science Inst., Univ. of California, Santa Barbara, CA 93106), J.L. Stoddard and C.A. Ochs

Most alpine and subalpine lakes of the Sierra Nevada (California) are very dilute, weakly buffered calcium-bicarbonate waters. Seventy-three lakes selected to lie in basins representative of Sierran bedrocks were sampled in the summers of 1981 and 1982 and have a median alkalinity of 59 μeq l⁻¹ (range, 5 to 113?), and pH of ? (range, 5.7 to 9.4). The alkalinity of Sierran lakes cannot be predicted from altitude, basin area, or lake area. The concentrations of sulfate, calcium or alkalinity in lake waters are positively correlated with the percent areal coverage of volcanic or calcareous rocks in the basins. The lakes are not acidified but are extremely sensitive to increases in acidity of atmospheric precipitation. (Chemistry of bodies of water, limnology, water quality.)

Water Resour. Res., Paper 4W1251.

Hydrology

1830 Groundwater
AN EXTENDED IDENTIFIABILITY IN AQUIFER PARAMETER IDENTIFICATION AND OPTIMAL PUMPING TEST DESIGN
W. W-G. Yeh (Civil Engineering Department, University of California, Los Angeles, California, 90024), N. Z. Sun (Department of Mathematics, Shandong University, The People's Republic of China)

An Extended Identifiability, called "δ-identifiability", is developed for groundwater modeling and management. Some fundamental concepts are developed for establishing a criterion in connection with the problem of optimal experimental design, such as the design of an optimum pumping test to assist aquifer parameter identification. The proposed "δ-identifiability" is based upon the concept of weak uniqueness. The determination of the admissibility of a given design is formulated as a nonlinear programming problem. The original constrained problem is transformed into solving a sequence of unconstrained problems by a Penalty Function Method. Numerical experiments are conducted to illustrate the proposed concept and algorithm.

Water Resour. Res., Paper 4W1157.

1860 Runoff and streamflow
MARKOV FLOW MODELS AND THE FLOOD WARNING PROBLEM
S. Yakowitz (Systems and Industrial Engineering Department, University of Arizona, Tucson, Arizona, 85721)

Let {Y(j)} represent periodically-sampled river discharge values. For simplicity, say that a flood occurs at epoch n+1 if, for some fixed T, Y(n+1)>T. Assume that at epoch n, the decision maker must decide whether or not to issue a flood warning, this decision being based on the past flow record {Y(j): j≤n}. Finally, assume that costs have been assigned to the two types of mistakes: the "false alarm" event and the event that a flood occurs when no warning was issued. It is argued that outside the Gaussian assumption, standard time series methodology is inappropriate for the flood warning problem.

The purpose of this paper is to relate recent progress based on alternate principles. A nonparametric inference procedure is described which converges to the optimal decision function for the flood warning problem as the length of the historical record increases, for essentially any stationary ergodic Markov process. Under additional assumptions, rates can be established and shown to be optimal in a certain sense. The new methodology is compared with ARMA predictors on simulated and river flow data.

Water Resour. Res., Paper 4W1253.

3180 Water Quality
CONVERSION OF ARIZONA CHAPARRAL TO GRASS INCREASES WATER YIELD AND NITRATE LOSS
E. A. Davis (Rocky Mountain Forest and Range Experiment Station, Forest Service, USDA, Arizona State University, Tempe, Arizona, 85181)

Converting an Arizona chaparral watershed to grass cover using a soil application of karbutilate granules increased streamflow and the nitrate content of the water. Nitrate concentrations in streamflow from an untreated control watershed remained less than 1 ppm throughout the study, whereas nitrate from the treated watershed increased during the first posttreatment year to a maximum concentration of 56 ppm, with an annual weighted mean concentration of 16 ppm. Maximum concentrations of 60 and 69 ppm occurred during the third and fourth posttreatment years, when annual mean concentrations were 66- and 100-fold above normal. After 11 years the annual mean concentration was still 14-fold above normal. The mean nitrate concentration of the streamflow from the treated watershed for the entire 11-year period was 29-fold greater than that for the control watershed. (Chaparral conversion, water yield increase, nitrate loss).

Water Resour. Res., Paper 4W1045.

Meteorology

3715 Chemical Composition and Chemical Interactions
PHOTOCHEMICALLY PRODUCED OZONE IN THE EMISSION FROM LARGE SCALE TROPICAL VEGETATION FIRES
A.C. Delany (National Center for Atmospheric Research P.O. Box 3000, Boulder, CO 80307) P. Haagenson, S. Walters, A.F. Wartburg, and P.J. Crutzen

An aircraft measurement program was undertaken in the savanna regions of central South America in the dry season of 1980 to investigate the atmospheric effects of large scale biomass burning. The smoke from the fires was found to be largely confined within an approximately 3 km deep boundary layer capped by a subsidence inversion or a stable layer. This condition typically persists for week long periods due to the synoptic subsidence occurring during the dry season. Photochemical production of ozone occurred in the polluted layer over the entire Cerrado region of central Brazil. The factors controlling the concentration of this ozone are examined and an estimate of the amount of ozone produced is reported. (Ozone, tropical, biomass, fires).

J. Geophys. Res., D, Paper 4D1246.

3735 Electrical Phenomena
ATMOSPHERIC-ELECTRICAL IMPLICATIONS OF ^{212}Pb DAUGHTER DEPOSITION ON VEGETATED GROUND
J. C. Willett (Naval Research Laboratory, Washington, D.C. 20375-5000)

Natural diffusive deposition of radon daughter products from the atmosphere onto an aerodynamically rough, vegetated surface may cause an important enhancement of the ionization rate within the plant canopy. For example, the blades of grass in a lawn may become slightly radioactive, leading to higher ionization in the air between them than above their tops. The impact of this increased ionization rate is estimated from a simple model of the conductivity profile in the turbulent "electrode layer". It is found that an order-of-magnitude augmentation can have substantial effects on the electrical structure.

With this motivation, a one-dimensional, steady state model of radon-daughter dry deposition is developed for estimating the magnitude of the deposited activity. The effects of aerosol attachment and of the entire decay chain are included. This model predicts significant enhancements of the surface radioactivity under typical continental conditions. (Atmospheric electricity, electrode effect, environmental radioactivity, dry deposition).

J. Geophys. Res., D, Paper 4D1155.

3745 Gravity Waves, Tides, and Compressional Waves
AN OBSERVATIONAL ESTIMATE OF GRAVITY WAVE DRAG FROM THE MOMENTUM BALANCE IN THE MIDDLE ATMOSPHERE
Anne K. Smith (National Center for Atmospheric Research*, P. O. Box 3000, Boulder, Colorado 80307), Lawrence V. Lyjak

The zonal average momentum budget in the middle atmosphere (up to 0.1 mb) is computed for seven months of satellite observations in order to determine the forcing needed to obtain a balance. This momentum residual includes forcing by waves with small zonal scales such as gravity waves. The results indicate that the forcing needed in the lower mesosphere reaches peak values of about 29 m s⁻¹ day⁻¹, which is large compared to the Rayleigh friction used in that part of the atmosphere in numerical models such as that of Holton and Wehrbein (1980a). The seasonal change follows that of Rayleigh friction; the Northern Hemisphere momentum deficit is large easterly in winter, decreases in the spring and becomes small westerly in late spring. However, the largest momentum deficits are in middle and high latitudes (50°–80°N) in winter, whereas the largest Rayleigh frictional damping is in the vicinity of the jet (30°–50°N).

The observations were also compared with the parameterized acceleration of the mean flow by gravity waves (Lindzen, 1981; Holton, 1983). The observations of the wintertime momentum residual are similar to the values used in the circulation model of Holton (1983). Derivation of the parameterization constant from the satellite observations results in an equivalent zonal wavenumber for gravity waves that is substantially smaller than that used by Holton (1983) in his model. Possible reasons for this difference are that many of the gravity waves break at levels above the region where data are available, and that gravity waves with non-zero phase speeds may be present.

*The National Center for Atmospheric Research is sponsored by the National Science Foundation.

J. Geophys. Res., D, Paper 4D1274.

Oceanography

4705 Boundary layer and exchange processes
EVIDENCE FOR WIND PUMPING OF AIR-SEA GAS EXCHANGE BASED ON DIRECT MEASUREMENTS OF CO_2 FLUXES
S. D. Smith and E. P. Jones (Atlantic Oceanographic Laboratory, Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, N. S., Canada, B2Y 4A2)

In a series of measurements of CO_2 flux over the sea the mean flux was near zero even though the surface water had substantially higher partial pressure of CO_2 than the air. Hourly variations in wind speed were well correlated with the flux, suggesting that a wind-driven process such as wave breaking and downward mixing of bubbles may drive additional CO_2 into the water as the wind speed increases. The traditional model of air-sea gas flux as a function of sea-air partial pressure difference was modified to include downward pumping by wind. We conclude that the flux of non-atmospheric gases such as radon does not serve as a complete model for the two-way surface flux of atmospheric constituents such as CO_2. (Gas flux, air-sea interaction).

J. Geophys. Res., C, Paper 4C1277.

4713 (Circulation)
THE SIMULATED RESPONSE OF AN UPPER-OCEAN DENSITY FRONT TO LOCAL ATMOSPHERIC FORCING
David Adamec (Department of Meteorology, Naval Postgraduate School, Monterey, CA 93943) and R.W. Garwood Jr. (Department of Oceanography, Naval Postgraduate School, Monterey, CA 93943)

Four numerical experiments with different atmospheric forcing are considered to investigate a variety of transient responses of an upper-ocean density front similar to the Maltese front (south of Sicily) in an embedded mixed layer – ocean circulation model. Of particular interest is a case that simulates forcing observed by Johannessen [1975]: in May 1971, measurements of the Maltese front were being taken in calm weather and then the wind suddenly increased to 10–15 m/s down the front. For this forcing, the model result is consistent with the observations predicting steepening of the frontal interface, spreading of the surface isopycnals and very little horizontal displacement of the surface front. However, the model predicts too much mixed-layer deepening and fails to predict the observed strengthening of the along-front flow. Three additional experiments are considered to assess the effects of a change in the wind direction and the inclusion of a surface buoyancy flux. The inclusion of a diurnal surface buoyancy flux produces a very different response from the simulations with no buoyancy flux: when the surface buoyancy flux is negative, the mixed layer reforms at a shallow depth, resulting in much higher advecting velocities and subsequently larger displacements of the surface front. The negative buoyancy flux can effectively protect the sub-surface structure with a shallow, stable surface layer. It also decouples the deeper frontal processes from the surface mixed-layer processes. (Numerical model, atmospheric forcing, mixed layer).

J. Geophys. Res., C, Paper 4C1257.

Particles and Fields—Interplanetary Space

5180 Solar wind plasma
THE FORMATION OF A STANDING SHOCK IN A POLYTROPIC SOLAR WIND MODEL WITHIN 1–10 R$_s$
Shadia R. Habbal (Harvard-Smithsonian Center for Astrophysics, 60 Garden St., Cambridge, MA 02138),

We show how a one fluid polytropic solar wind model exhibits properties similar to an isothermal wind when localized momentum addition and/or rapid area divergence produce multiple critical points in the flow. In particular, we show that, when the sonic transition in the flow occurs closer to the coronal base, multiple steady solutions can exist. These multiple steady solutions consist of a continuous solution passing through the innermost critical point and other steady solutions involving a steady shock transition. By following the temporal evolution of the solar wind from a steady state with one critical point to a steady state with three critical points, we show that a standing shock solution is more likely to develop than a continuous solution when momentum deposition occurs close to the coronal base and the equation of motion admits multiple steady solutions. This result is particularly relevant to the solar wind when momentum deposition occurs as a result of a rapidly diverging coronal hole geometry. (Temporal evolution, multiple wind solutions, standing shocks).

J. Geophys. Res., A, Paper 4A8140.

Particles and Fields—Ionosphere

5545 Ionospheric disturbances
A LABORATORY INVESTIGATION OF THE HIGH-FREQUENCY FARLEY-BUNEMAN INSTABILITY
B. Kustom (Dept. of Physics and Astronomy, University of Iowa, Iowa City, Iowa 52242), N. D'Angelo and R. L. Merlino

A laboratory investigation of the high-frequency Farley-Buneman instability is described. The instability was studied theoretically by Lee et al. [1971] and is predicted to occur in the low E region of the ionosphere when the E/B drift velocity of the electrons relative to the ions is several times C_s, the ion-acoustic speed. In our experiments, an increase of the electric field well above the Lee et al. "threshold" merely enhances the general power level of the fluctuations but does not affect appreciably their spectral shape. The observed frequency spectra fall off very rapidly with increasing frequency, with a spectral shape of the type P(f) ∝ $f^{-3.5}$. This result has negative implications for a recently proposed mechanism of "anomalous" wave electron heating in the lower E region of the ionosphere. (Ionospheric disturbances, Farley-Buneman instability).

J. Geophys. Res., A, Paper 4A8095.

EXPERIMENTAL RESULTS FROM THE "HERO" PROJECT: IN SITU MEASUREMENTS OF IONOSPHERIC MODIFICATIONS USING SOUNDING ROCKETS
G. Rose (Max-Planck-Institut für Aeronomie, D-3411 Katlenburg-Lindau, F. R. Germany), B. Grandal, E. Neske, W. Ott, K. Spenner, J. Holtet, K. Måseide, J. Trøim

During the HEating ROcket project HERO four instrumented payloads were launched on sounding rockets from Andøya Rocket Range in autumn 1982 to measure in situ the modifications of F-layer heights set up by the Heating facility at Ramfjord near Tromsø in Northern Norway. Coherent spectra of the 3 electric field components of the locally generated electron plasma waves were obtained in a 50 kHz wide band near the reflection level of the heating wave and the amplitude and phase of the 3 components of the electric and magnetic fields of the heating wave were measured simultaneously. At the same time the ion-acoustic frequency range was monitored and quasi-continuous measurements were made on several fixed frequencies from 4 kHz to 16 kHz below the heating frequency using linear dipole antennas. Moreover, measurements were made of electron temperature, suprathermal electrons and local electron density along the rocket trajectory. The obtained data were characterized by strong fluctuations within the 1 second time intervals when the heating transmitters were turned on, by variable frequency spectra, by large amplitude variations and by no one-to-one correlation with the heating wave amplitude. (Ionospheric modifications, plasma waves, in situ measurements).

J. Geophys. Res., A, Paper 4A8244.

Particles and Fields—Magnetosphere

5865 General (Plasma Instabilities)
SPECTRAL BROADENING OF VLF TRANSMITTER SIGNALS OBSERVED ON DE-1: A QUASI-ELECTROSTATIC PHENOMENON?
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Spectrally broadened VLF transmitter signals are observed on the DE-1 satellite using alternatively both electric and magnetic field sensors. It is found that at times when the electric field component undergoes significant bandwidth expansion (up to ~ 100 Hz) the magnetic field component has a bandwidth of less than 10 Hz. The result support the theory that the off carrier components are quasi-electrostatic in nature. Measurement of the absolute E- and B-field magnitudes of the broadened signals are used to determine the wave Poynting vector. It is found that the observed power levels can be understood without invoking any strong amplification process that operates in conjunction with the spectral broadening. The implications of this finding in distinguishing among the various possible mechanisms for spectral broadening are discussed. (Satellite observations, spectral broadening, transmitter signals).

J. Geophys. Res., A, Paper 4A8277.

Planetology

6575 Surfaces of Planets
SPECTRAL ANALYSIS OF GROOVE SPACING ON GANYMEDE
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Grooves on Ganymede are interpreted as extensional tectonic features whose regular spacing is an indicator of the thickness of a brittle surface layer, or lithosphere, at the time of deformation. We have performed a statistical analysis of groove spacing on Ganymede, taking Fourier transforms of 157 photometric profiles across sets of grooves and examining the resultant power spectra for peaks representing the dominant topographic periodicities. The distribution of groove spacing on Ganymede is approximately log normal, with a minimum of 3.5 km, a maximum of 17 km, and a mean of 8.4 km. There is no correlation of groove spacing with latitude or longitude. The most striking feature of the geographic distribution is that, while groove spacing tends to be quite constant within a given groove set, it can vary substantially from one groove set to another in a geographic region. An exception is the Uruk Sulcus region, with a mean groove spacing of 6.5 km and very little variability. We examine several models that relate the observed groove spacing to lithospheric thicknesses. The most important conclusion is that lithospheric thickness varied significantly from one groove set to the next while grooves were being formed. We examine four possible causes for the heterogeneous distribution: variation in time of formation during a period in which the global mean heat flow was changing, variation in strain rate from one groove set to the next, local excursions in geothermal gradient caused by variations in the vigor of underlying convective upwellings, and local excursions in geothermal gradient caused by resurfacing events. The first three appear viable, while the fourth requires very rapid groove formation due to the short cooling times involved. (Ganymede, tectonics)

J. Geophys. Res., B, Paper 4B5060.

Tectonophysics

8150 Plate tectonics
A SIMPLE MODEL OF WHOLE-MANTLE CONVECTION
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Isotopic evidence of the chemical variability of basalts implies the existence of distinct, long-lived chemical reservoirs in the mantle. This has commonly been interpreted as evidence that mantle convection is layered, since known models of whole-mantle convection have too much shearing to allow preservation of these reservoirs. However, the geochemical evidence requires at least three reservoirs and models of layered convection have dynamical difficulties, casting serious doubt on the viability of these models. This difficulty has been resolved in the present paper by the development of a simple model of whole-mantle convection which allows the preservation of chemically distinct reservoirs. In this model, heating of the mantle from below produces axisymmetric plumes which carry heat upward through the mantle without causing overturning. Hence the lower mantle is much less sheared than in the usual two-dimensional model. Mantle convection is driven by the penetration of cold lithospheric slabs from above. It is argued that the pattern of convection is governed primarily by the dependence of viscosity on temperature and this dependence drives the mantle toward an isoviscous state. These ideas are quantified in a simple one-dimensional model of mantle convection in which the slab mass flux as a function of radius is governed by the requirement that the temperature profile remains isoviscous. The resulting convection cycles material through the upper mantle more rapidly than through the lower mantle. This provides a mechanism for an initially homogeneous mantle to become chemically stratified with a depleted upper mantle and primitive lower mantle.

J. Geophys. Res., B, Paper 4B1217.

8199 General Tectonophysics
DISPLACEMENT AND STRAIN PATTERNS OF EXTENSIONAL OROGENS
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Rock fabrics that result from displacement in extensional orogens provide a means of identifying geometric models responsible for extension of continental crust. Strain compatibility arguments indicate that a finite extension can be accommodated by displacements across (1) planar, nonrotating faults or ductile shear zones, (2) shear zones which rotate above a horizontal detachment (the domino model), or (3) shear zones which rotate as a result of a horizontally oriented, pure shear stretching component (the plastic model). Listric, normal shear zone geometries may develop as the result of a depth dependent change in the pure shear component (in the plastic model) or the area loss component (in the planar shear zone model). Within the geometric framework of these various models, the effects of superposed simple shear, pure shear extension, and area change on the rock fabric are investigated. These displacement components, which may be superposed sequentially or simultaneously, determine the state of finite strain associated with a given magnitude of tectonic extension. The relationships between displacement and strain are expressed as graphs of foliation dip (or strain ratio) versus shear strain and as graphs of foliation dip (or strain ratio) versus tectonic extension. The shear strain graphs illustrate the effects of the different displacement components on the rock fabric in a single shear zone, whereas the tectonic extension graphs better illustrate these effects on the regional scale. The shear strain and tectonic extension graphs can be used by field geologists (1) to determine tectonic extension across a region from measurements of strain ratio or orientation and fluctuation of foliation, (2) to distinguish between possible extension models from field data, and (3) to evaluate the influence of shear zone attitude and thickness upon the amount of displacement. Applications of these methods are illustrated for field areas in metamorphic core complexes of Arizona and in the Basin and Range province of the North America Cordillera. (Tectonics, strain, continental rifting).

Tectonics, Paper 4T0968.

Volcanology

6699 Volcanology
THE MAY 18, 1980 ERUPTION OF MOUNT ST. HELENS II: MODELLING OF DYNAMICS OF PLINIAN PHASE
H. S. Carey and H. Sigurdsson (Grad. School of Oceanography, University of Rhode Island, Narragansett, R.I., 02882)

The plinian phase of the May 18, 1980 Mt. St. Helens eruption is modelled as a steady-state discharge of dacitic magma from a reservoir at 7 to 10 km depth at a rate of 1.9×10^7 kg/s. Properties of the magma, including pre-eruption volatile content (4.6% in the melt), temperature (920–940°C), and confining pressure (190–250 MPa) are constrained by petrologic studies. Mass eruption rate, magma viscosity and independent estimates of magma ascent velocity suggest a 95 meter diameter conduit at a depth below vapor saturation. Dispersal of pyroclasts indicates a minimum exit velocity of roughly 200 m/s during the plinian phase. An upper limit of 310 m/s is obtained from the total amount of exsolved volatiles. Model-derived vent diameters based on 0.1 MPa exit pressure, petrologically-inferred magma properties and known mass eruption rate, range from 105 to 175 meters with a flared configuration. The calculated vent diameter, mass eruption rate and exit velocity define conditions close to the transition between convective column rise and column collapse. These results are consistent with the sporadic generation of pyroclastic flows during a period characterized mainly by a sustained eruption column.

J. Geophys. Res., B, Paper 4B5075.

Information Related to Geologic Time

9260 Pacific Ocean
NEAR EQUATORIAL CTD OBSERVATIONS AT 85°W IN OCTOBER 1982
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CTD data collected about the equator along 85°W between 8 and 12 October 1982 are used to investigate stratification changes in the upper 1 km associated with the 1982/83 El Niño. With respect to the thermal field observed in November 1981, virtually the entire section exhibited downward displacements in the upper kilometer of the water column. Observed displacements at the depth of the mean thermocline were large, ~ 150 m, and relatively symmetric about the equator. Displacements around 1 km depth were near zero. This stratification change appears to have been produced by a zonal convergence of mass at temperatures above 15°C with divergence below. Least square modal decompositions of the vertical displaced profiles revealed significant contributions from modes 1 and 2 with meridional structure consistent with Kelvin waves. The observations thus support current theories that relate El Niño onset in the eastern Pacific to anomalous wind forcing in the west. (El Niño, Kelvin waves).

J. Geophys. Res., C, Paper 4C1122.

General or Miscellaneous

9460 General (Coupled Phenomena in Rocks)
COUPLED THERMAL-HYDRAULIC-MECHANICAL PHENOMENA IN SATURATED FRACTURED POROUS ROCKS—NUMERICAL APPROACH
J. Noorishad (Lawrence Berkeley Laboratory, University of California, Berkeley, California, 94720), C. F. Tsang and P. A. Witherspoon

The fundamentals of the theory of consolidation and thermoelasticity are recast into the formulation of a phenomenon called thermohydroelasticity. Subsequently, a variational principle and Galerkin formulation are combined with the finite-element method to develop a new technique to investigate coupled thermal-hydraulic-mechanical behavior of liquid-saturated, fractured porous rocks. A code-to-code verification of the method is performed. Finally, the environment of a heater emplaced in hard rock is simulated. The effects of the coupled thermal stresses in the fractured rock are evident from the dramatic reduction of permeability due to the deformation of the fractures. These results can improve the understanding of observations and displacement measurements made in the insitu experiments at the Stripa mine in Sweden. (Coupled Phenomena, fracture flow, thermoelastic consolidation).

J. Geophys. Res., B, Paper 4B0953

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